ANTARES neutrino telescope: Status report

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Outline

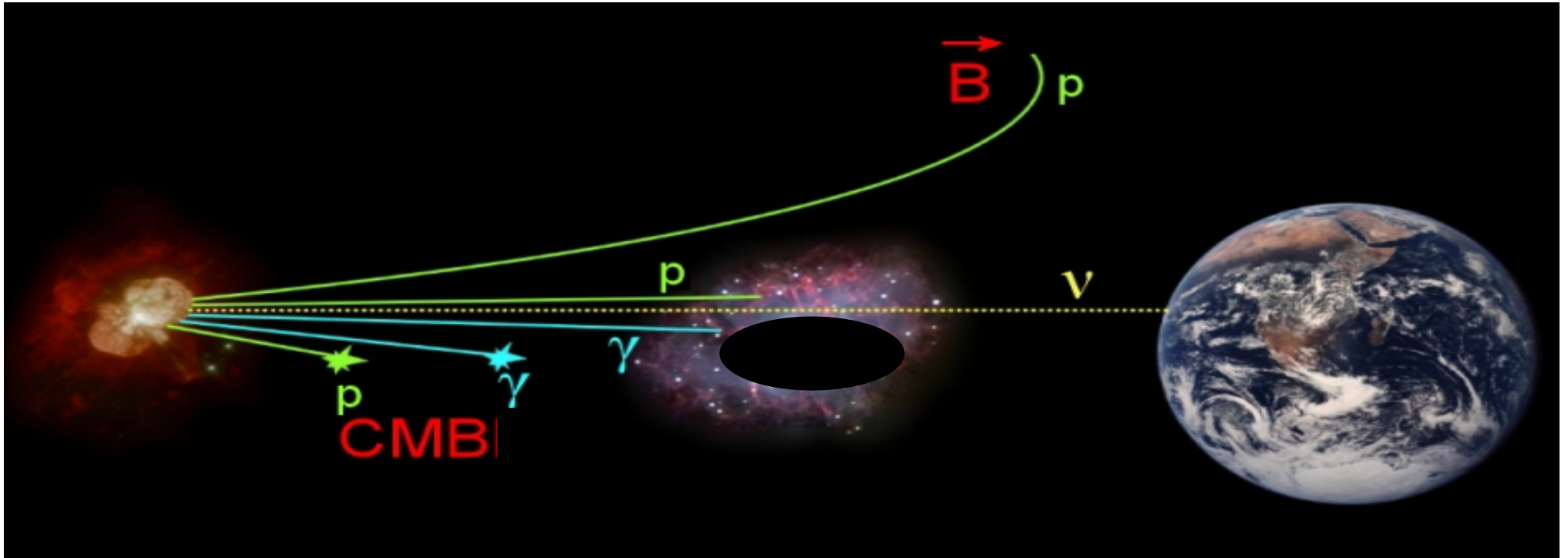
1) Introduction
    - Why ? How ? What ?
2) Results and ongoing analysis
    - Atmospheric muons
    - Search for cosmic neutrinos
        - Diffuse flux
        - Point sources
        - Dark matter
    - Multi messenger
3) Conclusion

Why neutrinos?

Photons: interact with CMB and background light

Protons: deflected by magnetic fields ($E<10^{19}$ eV)
and interact with CMB ($E>10^{19}$ eV => <30 Mpc)

Neutrinos: weakly interacting (cosmological distances)
point back to source of emission
Disadvantage => required large detector volume



How to produce cosmic neutrinos?

Photon astronomy found sources with E> 100 TeV

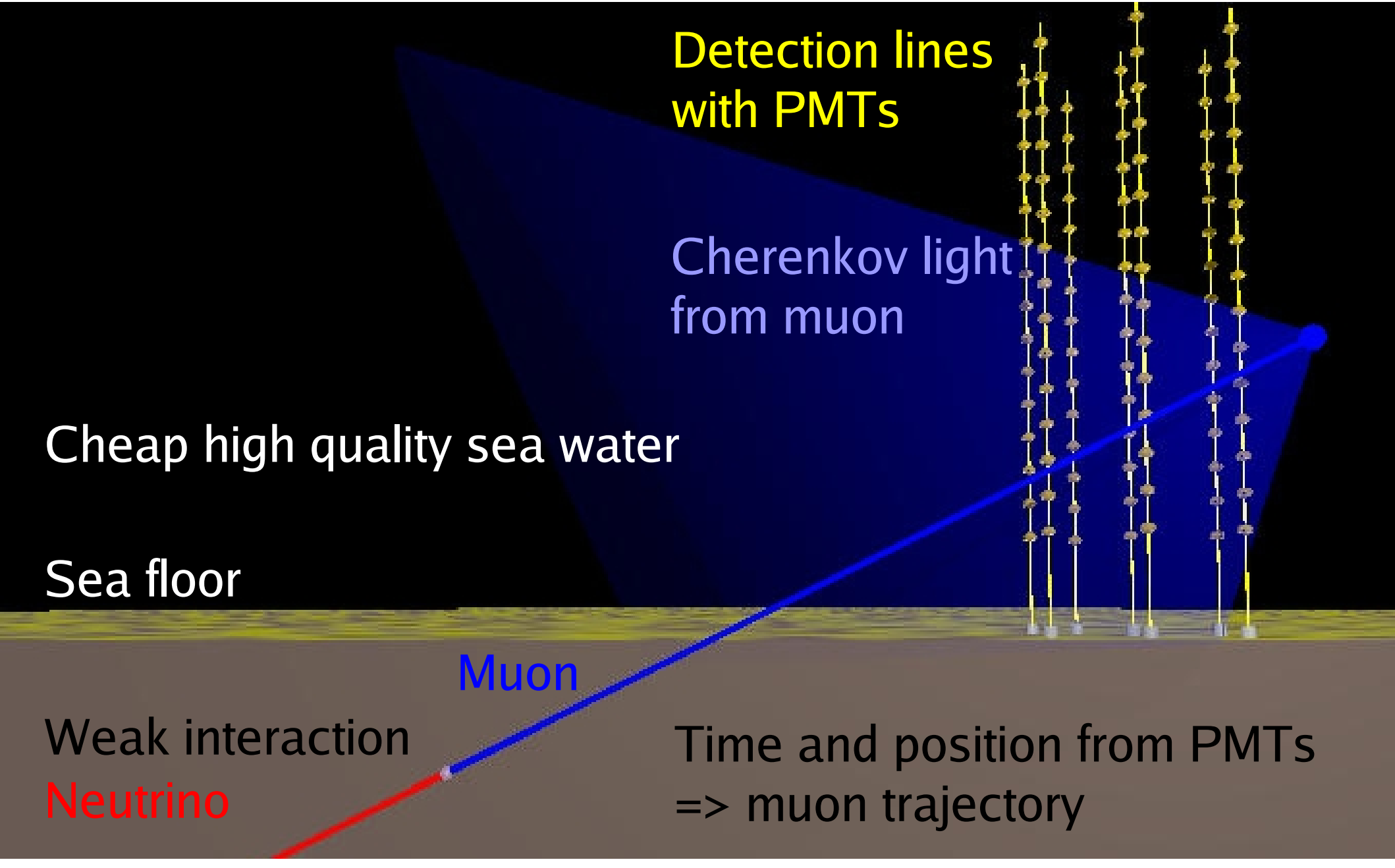
If hadron acceleration:

Accelerating p + X => mesons + X => neutrino/photons + X

Photon energy ~ Neutrino energy
Photon density ~ Neutrino density

Very energetic objects:
Galactic (Super Nova Remnants)
Extragalactic (Active Galactic Nuclei and Gamma Ray Burster)

How to measure neutrinos?



What is ANTARES?

In the Mediterranean Sea

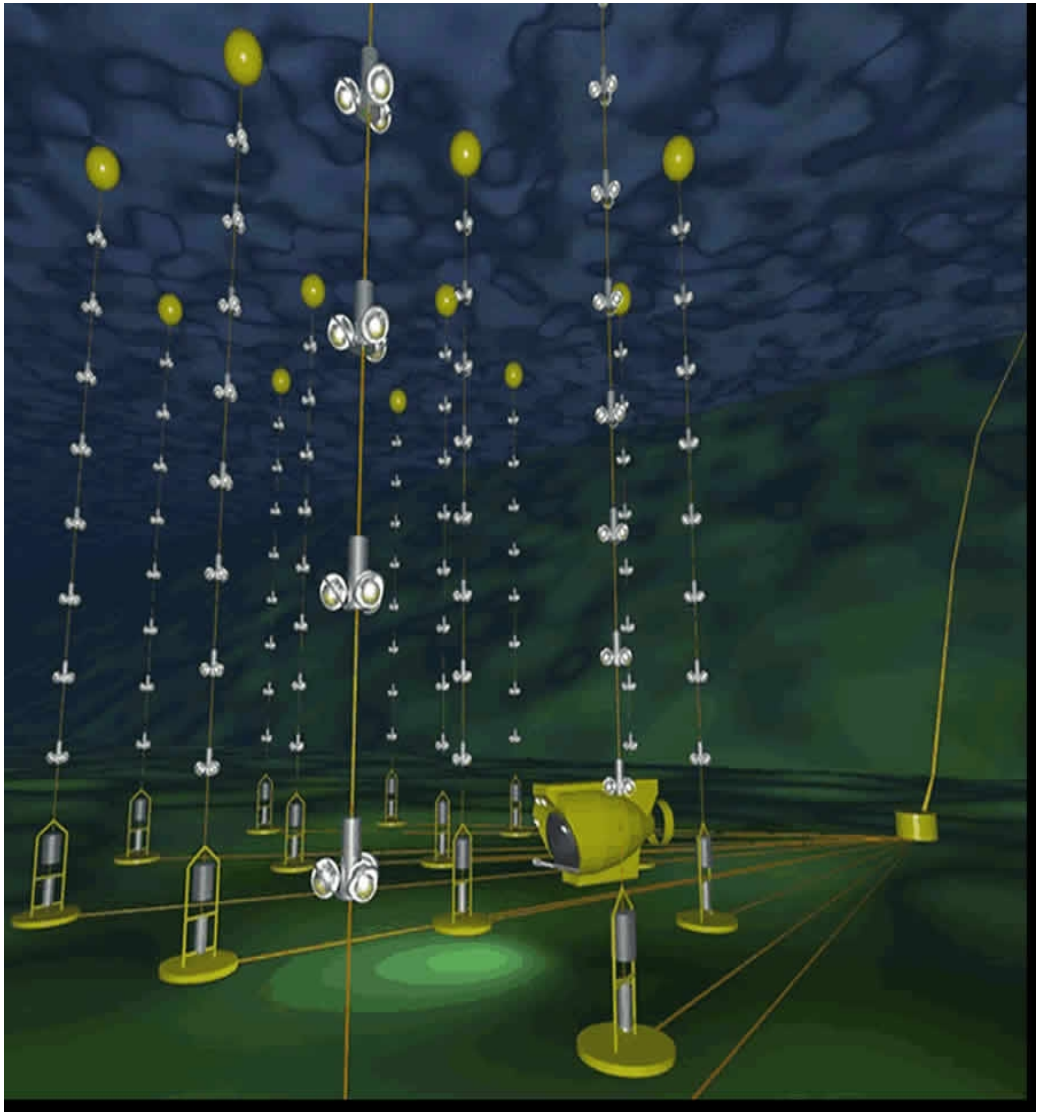
Installed off French coast

2.5 km under water

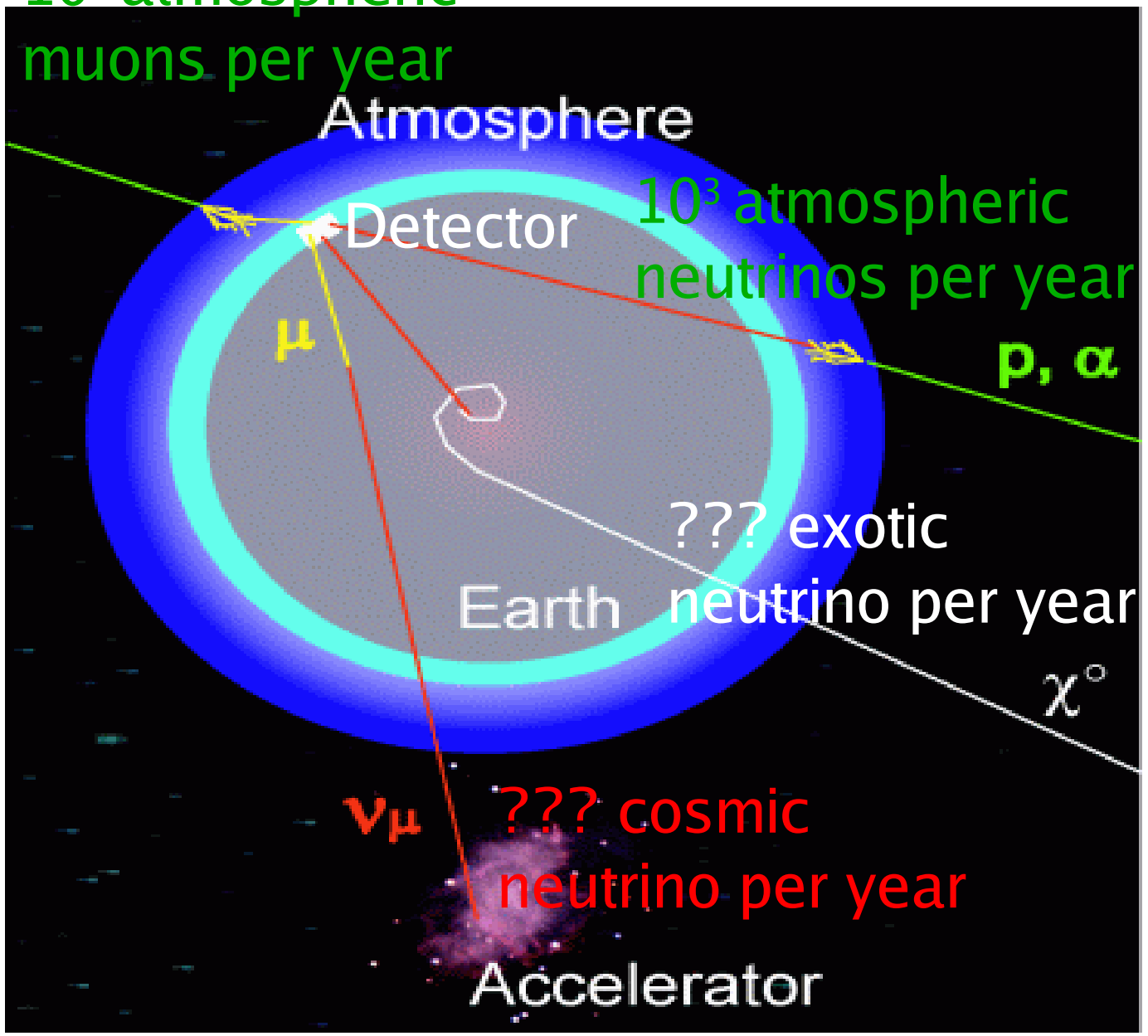
12 Lines (885 PMTs)

Completed in May 2008

Data taking started soon after installation of the first line in 2006



What does ANTARES measure?



Earth shielding rejects atmospheric muons

upward going muon = neutrino-induced event

Results and ongoing analysis

Astroparticle Physics:

- Diffuse flux
- Point sources
- Neutrino oscillation

Particle physics:

- Atmospheric muon flux
- Cosmic rays anisotropy/composition
- Electromagnetic showers

Searches:

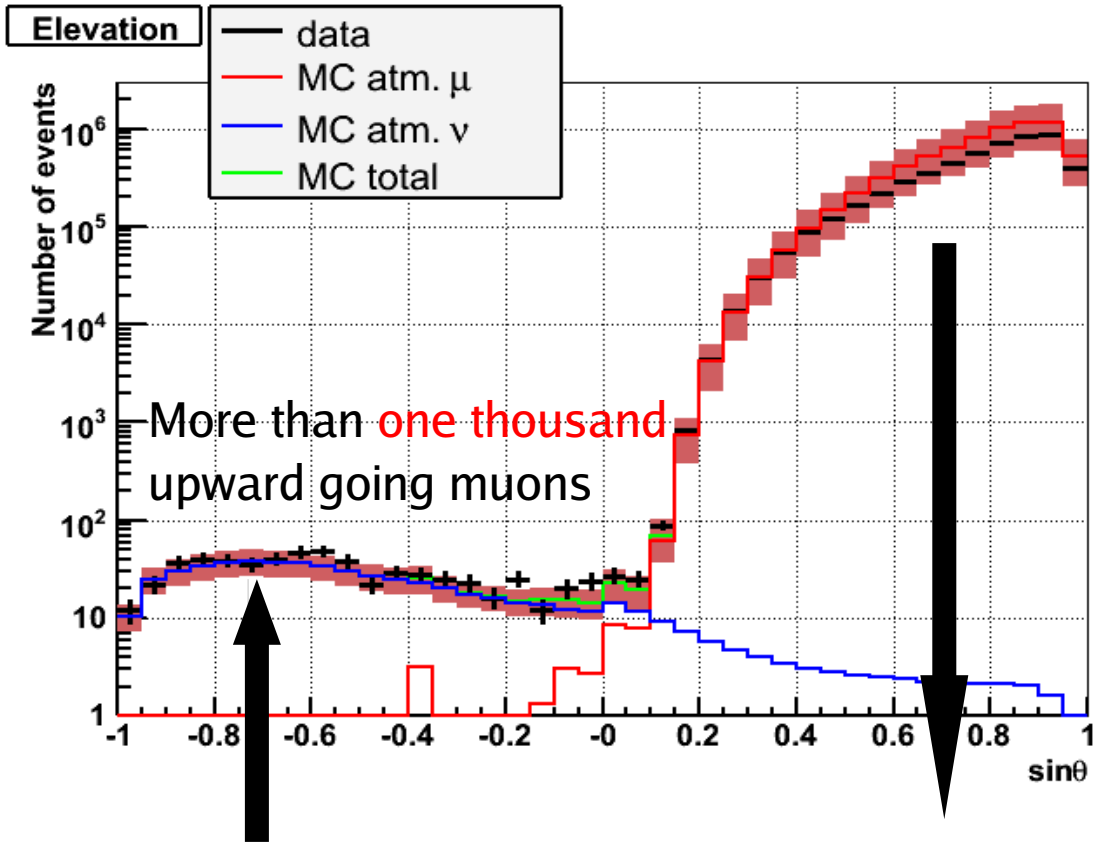
- Dark matter
- Multi messenger astronomy
- Magnetic monopoles/Nuclearites

Detector related:

- Timing/positioning
- Water absorption length/refractive index
- Acoustic

Atmospheric neutrinos and muons

2007-2008 => 341 days of detector lifetime



Robust muon reconstruction method
=> minimizes time residuals
assuming hits from
Cherenkov photons

Simulation uncertainties:
- Theoretical (Flux)
- Detector (PMT, environment)

=> atmospheric muons (50% error)
=> atmospheric neutrinos (30% error)

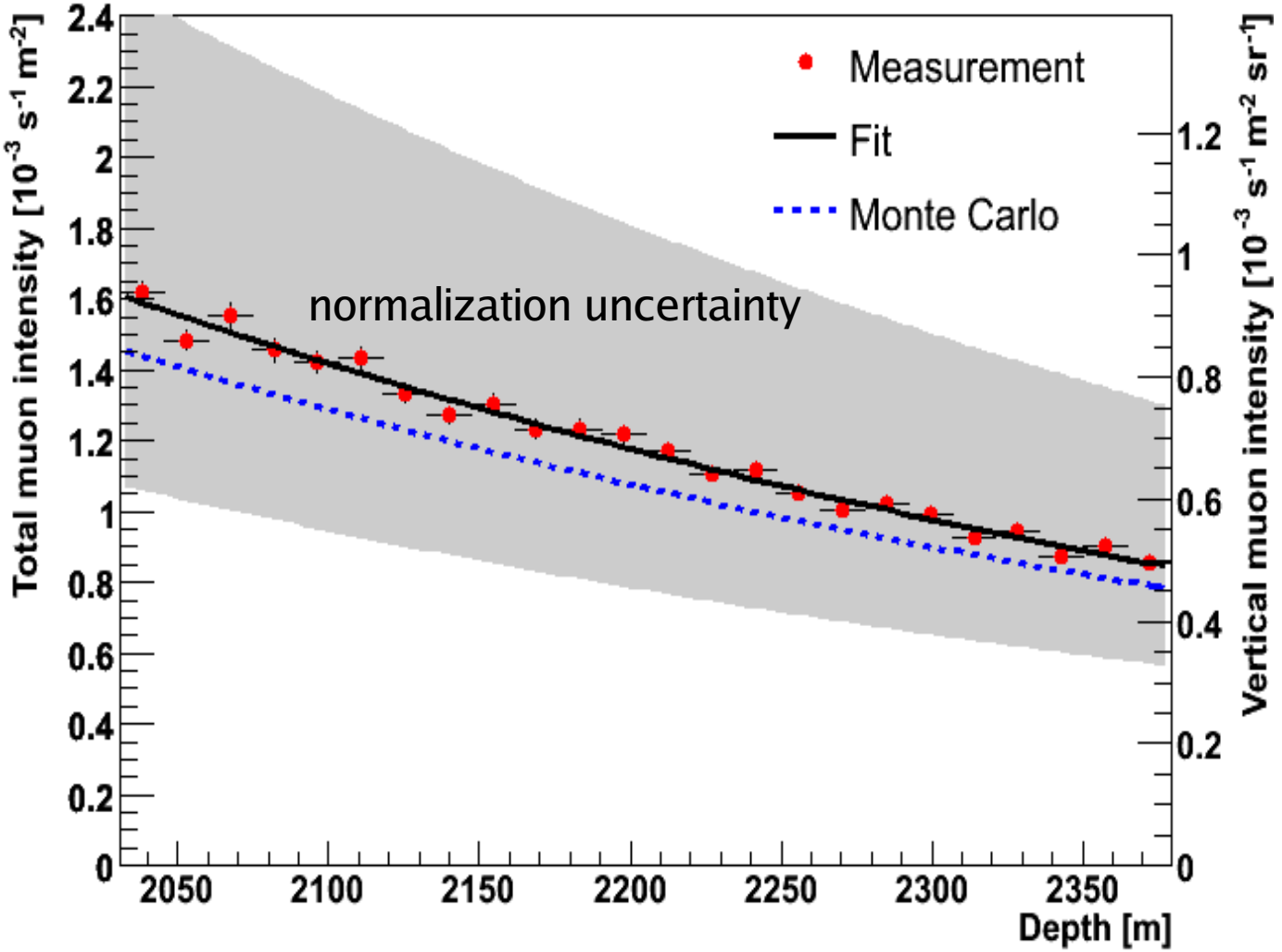
Upward going muons produced by neutrinos, only particles which cross whole Earth

Downward going cosmic-ray muons, which reach apparatus despite shielding provided by 2 km of water

Antares measures around 3 neutrinos per day

Atmospheric muons

Atmospheric muon flux

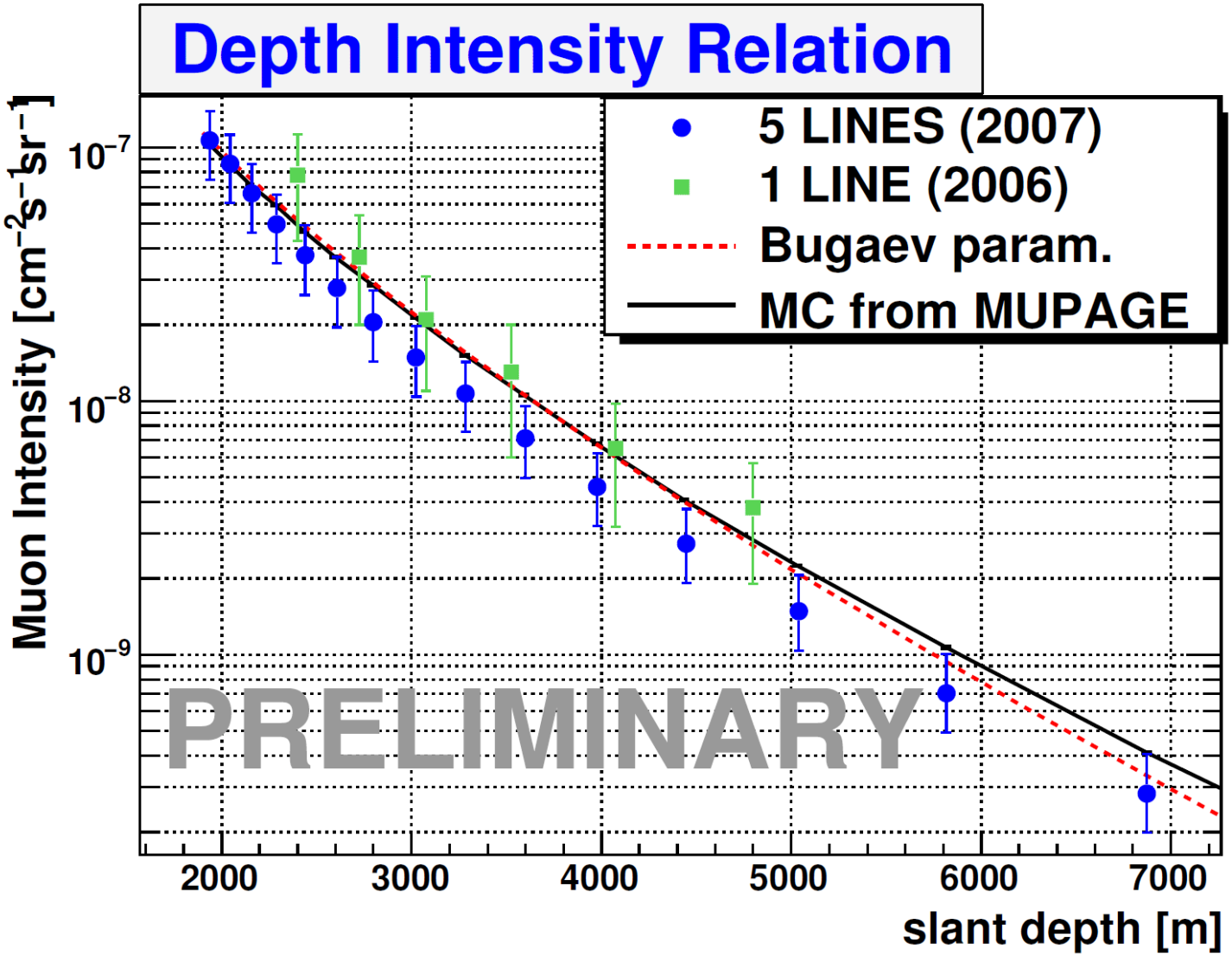


Simple:
Method based on time coincidences on adjacent detection storeys.

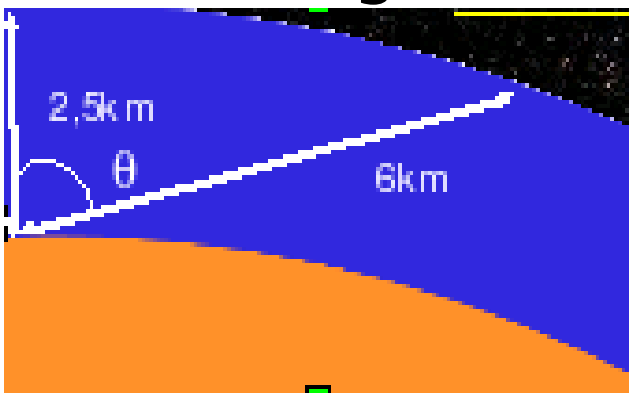
No muon direction reconstruction needed.

Low energy threshold (~4 GeV) given by minimum track length (14.5 m) to reach adjacent detection storeys.

Atmospheric muon flux



Track length:

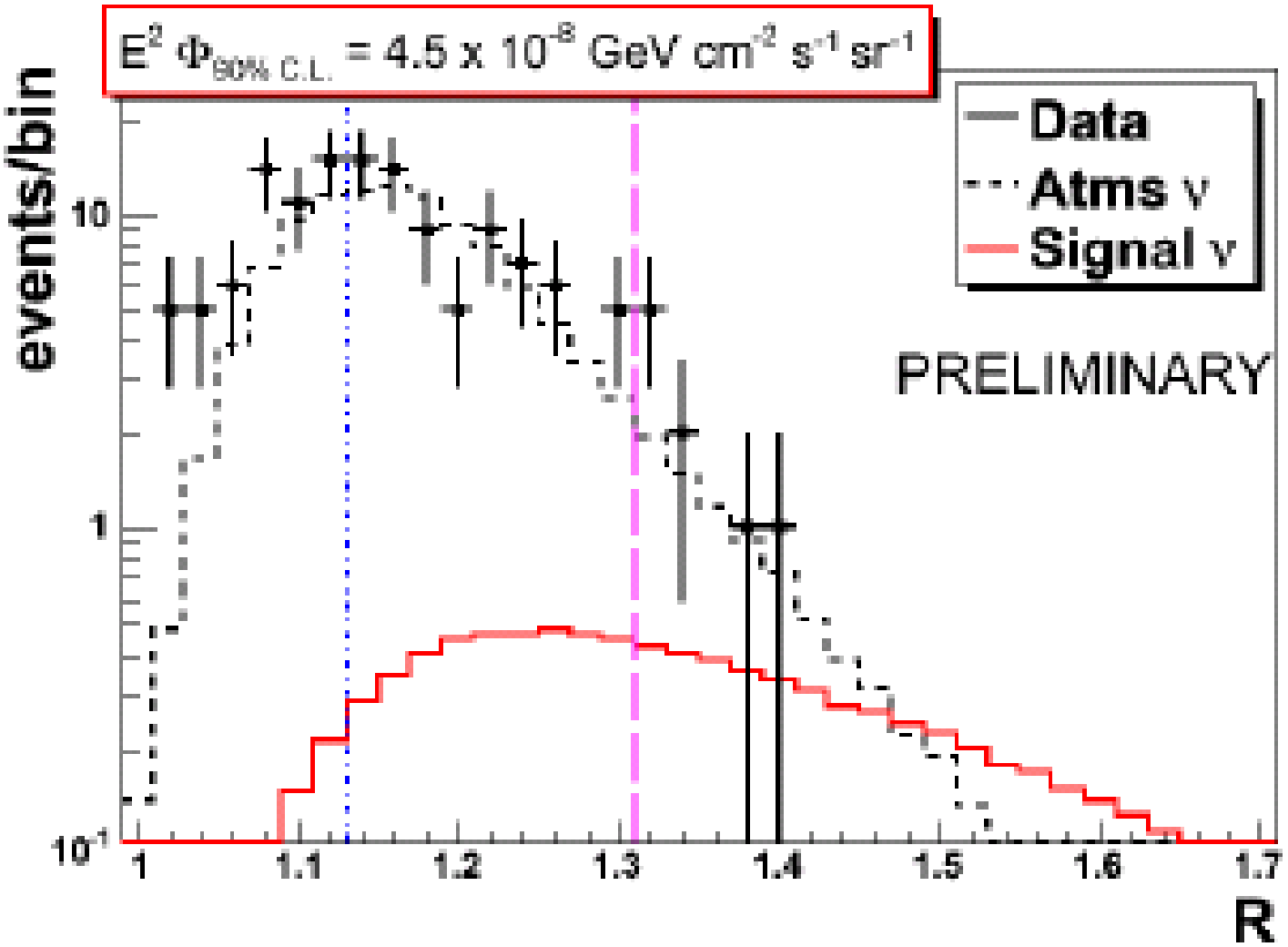


Systematic errors:
Environmental and geometrical characteristics of detector

Consistent with other experiments like:
AMANDA
BAIKAL
....

Search for cosmic neutrinos

Search for diffuse flux of muon neutrinos (2007-2009)



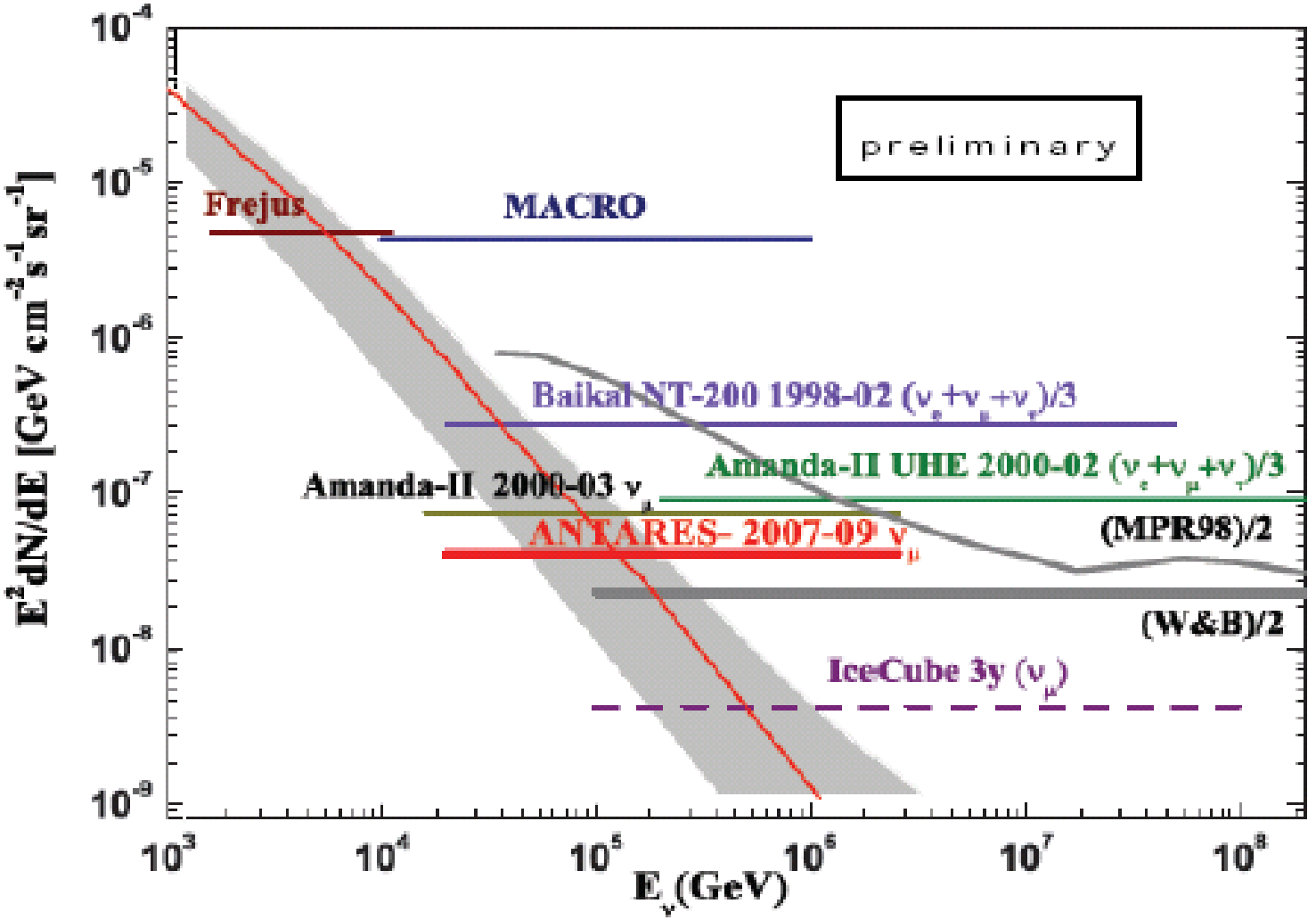
R=Energy estimator

Search high energy (>100TeV) cosmic neutrinos over atmospheric neutrinos => Energy estimator

No use of time or location information

Model rejection factor technique defines cut => 9 data events expected [8.4,12.5]

Upper limit on diffuse flux of muon neutrinos



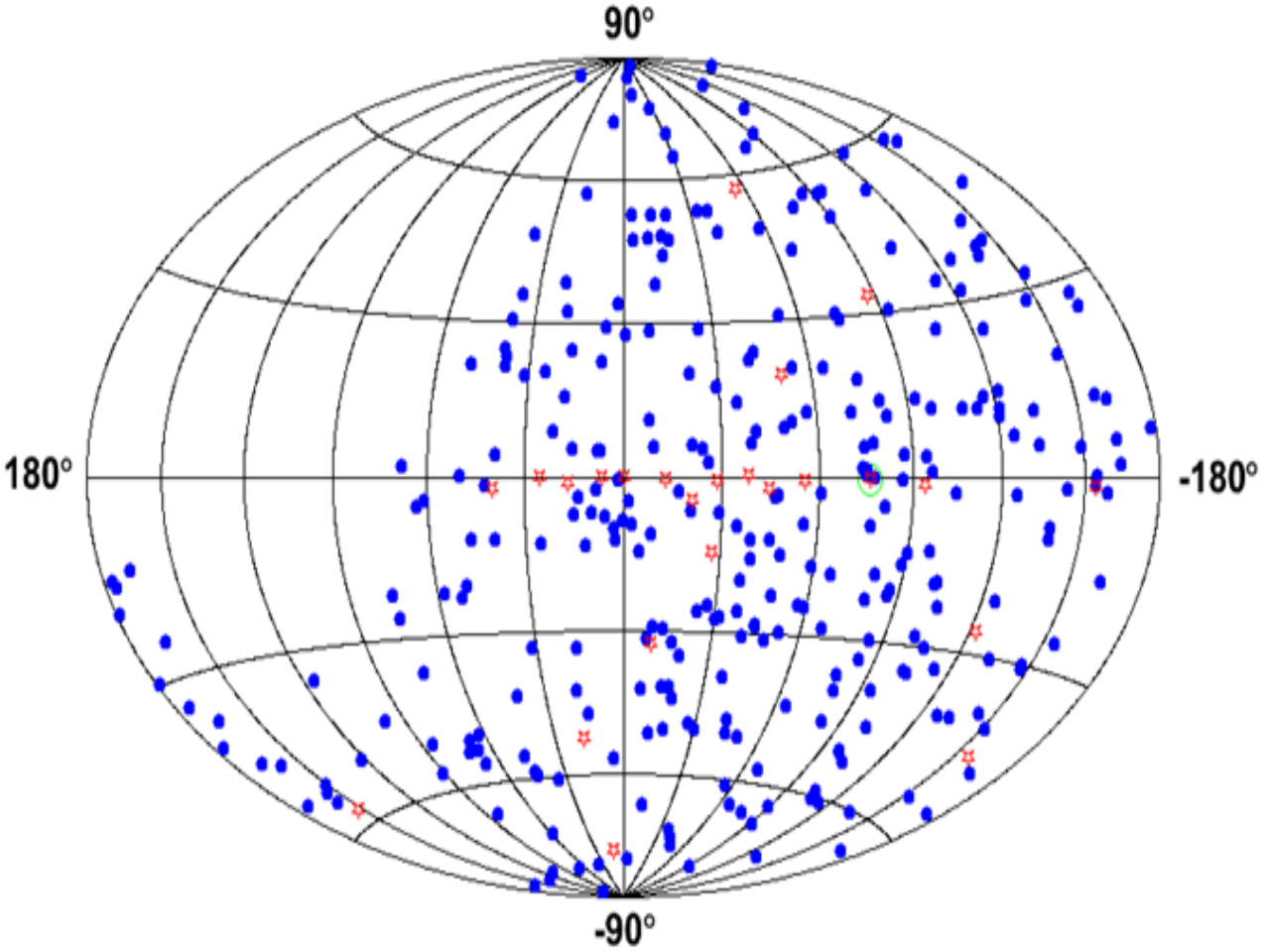
$$E^2\ \Phi(E)_{90\%CL} = 4.5^{+2}_{-1} \times 10^{-8}\ \mathrm{GeV\ cm^{-2}\ s^{-1}\ sr^{-1}}$$

2007-2009 data with three different detector geometries

Most sensitive upper limit!

Search for cosmic neutrinos

Galactic coordinates



Take direction and time of 314 neutrinos candidates from 2007 data (blue points) => Sky map

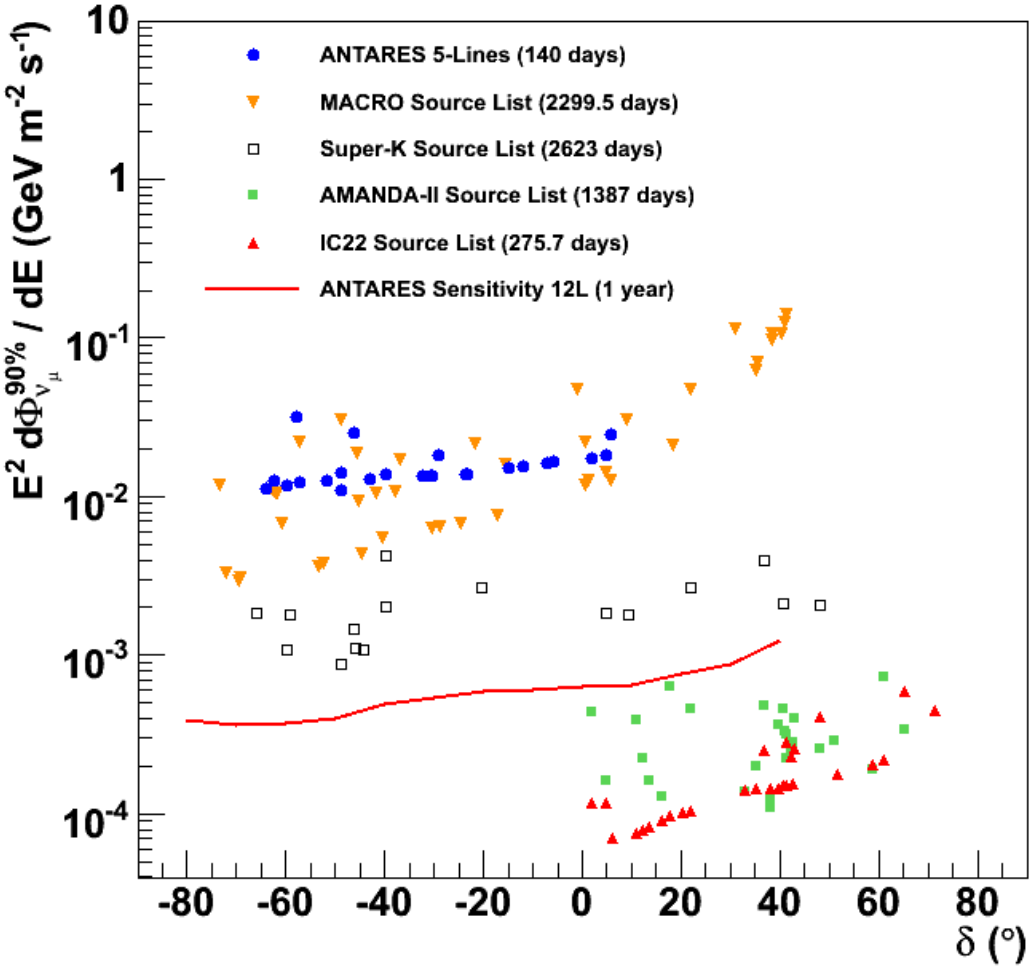
Search cluster of neutrinos from particular region on sky => Signature of astrophysical source

Higher discovery potential by choosing 24 interesting sources (red stars)

Most significant cluster (<2sigma) for HESS J1023-575 source.

Look for neutrino excess in source region

Upper limits



Search for neutrinos from Sun

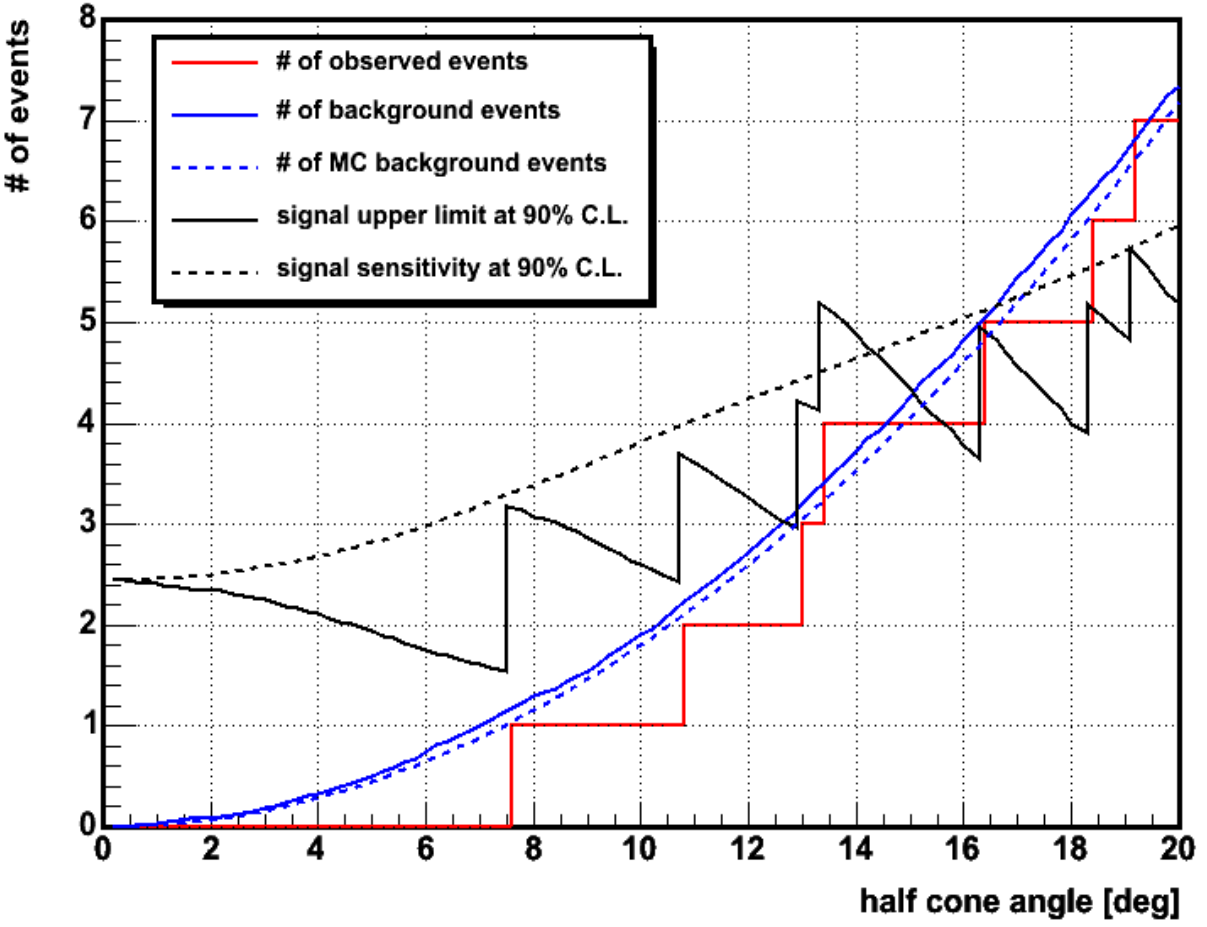
Model: Neutralinos gravitationally trapped in Sun
Neutralinos annihilation => neutrinos from Sun

Event rate in search cone around Sun

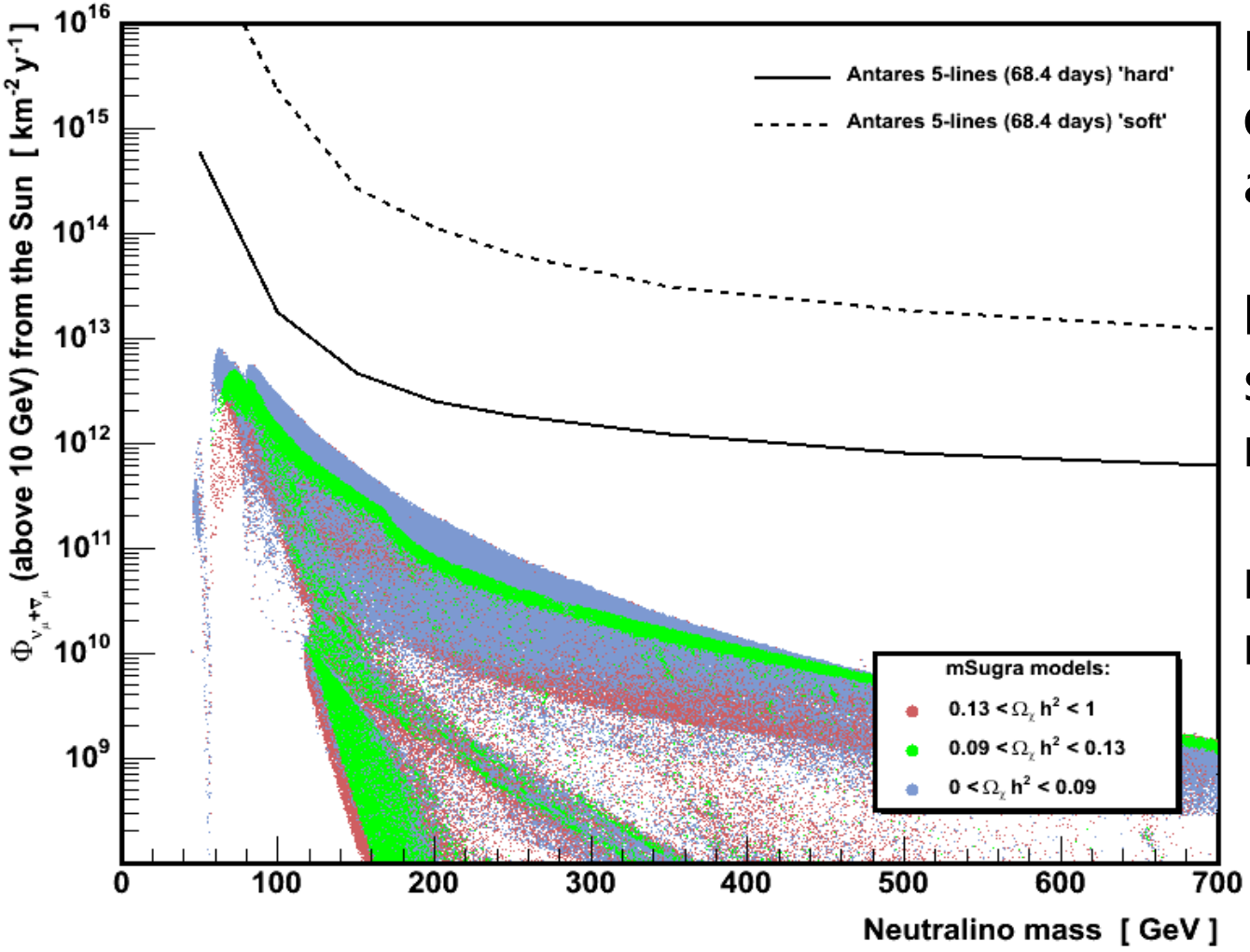
Search for neutrino events coming from Sun.

Take cone around Sun for 2007 neutrino sample (68 effective days).

Number of observed events agrees with the expected background.



Upper limits on neutrino flux from neutralino annihilation in Sun



Limit with b-quark (soft) or W-boson (hard) annihilation channel

Neutralino dark matter sensitivity within SUSY mSUGRA framework

mSUGRA parameter space not reached with 2007 data

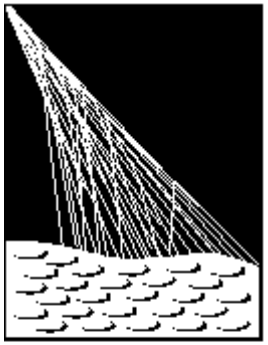
Multi messenger approaches

Use coincidence (time/location) to improve discovery potential

Correlation with gravitational waves (Ligo/Virgo)

Receive Gamma Ray Bursts alerts from satellites (GCN)

Directional correlation with high energy particles



PIERRE AUGER OBSERVATORY

ANTARES

Send alert for optical follow-up (TAROT)

Conclusion

- Antares has been taking data since 2006
- Antares is a neutrino telescope, but also a cosmic ray detector
- Broad physics program
- Starts to produce competing results

Backup Slides

Candidates Sources

Table 4: *Golden*-list for the 5-line data analysis

Name	Class	Equatorial coordinates RA	δ	Galactic coordinates l	b	Vis.
Galactic Sources						
HESS J0632+057	AMB	$6^h\ 32^m\ 58^s$	5° 48′ 20″	205.66	-1.44	0.46
RX J0852.0-4622	SNR	$8^h\ 52^m\ 00^s$	-46° 22′ 00″	266.28	-1.24	0.91
HESS J1023-575	AMB	$10^h\ 23^m\ 18^s$	-57° 45′ 50″	284.19	-0.39	1
PSR B1259-63	Binary Pulsar	$13^h\ 02^m\ 49^s$	-63° 50′ 02″	304.19	-0.99	1
RCW 86	SNR	$14^h\ 42^m\ 43^s$	-62° 29′ 00″	315.79	-1.46	1
Cir X-1	XRB	$15^h\ 20^m\ 41^s$	-57° 10′ 00.26″	322.12	0.04	1
HESS J1614-518	NCO	$16^h\ 14^m\ 19^s$	-51° 49′ 12″	331.52	0.58	1
GX 339	XRB	$17^h\ 02^m\ 49^s$	-48° 47′ 23″	338.94	-4.33	0.99
RX J1713.7-3946	SNR	$17^h\ 13^m\ 00^s$	-39° 45′ 00″	347.28	-0.38	0.75
Galactic Center	AMB	$17^h\ 45^m\ 41^s$	-29° 00′ 22″	359.95	-0.05	0.66
W28	SNR	$18^h\ 01^m\ 42^s$	-23° 20′ 06″	6.66	-0.27	0.62
LS 5039	XRB	$18^h\ 26^m\ 15^s$	-14° 49′ 30″	16.90	-1.28	0.57
HESS J1837-069	AMB	$18^h\ 37^m\ 38^s$	-6° 57′ 00″	25.18	-0.12	0.52
SS 433	XRB	$19^h\ 11^m\ 50^s$	4° 58′ 58″	39.69	-2.24	0.48
extra-Galactic Sources						
RGB J0152+017	HBL	$1^h\ 52^m\ 40^s$	1° 47′ 19″	152.38	-26.61	0.49
1ES 0347-121	HBL	$3^h\ 49^m\ 23^s$	-11° 59′ 27″	201.93	-45.71	0.55
PKS 0548-322	HBL	$5^h\ 50^m\ 40.6^s$	-32° 16′ 16.4″	237.56	-26.14	0.69
1ES 1101-232	HBL	$11^h\ 03^m\ 38^s$	-23° 29′ 31″	273.19	33.08	0.62
3C 279	FSRQ	$12^h\ 56^m\ 11^s$	-5° 47′ 21″	305.10	57.06	0.51
Centaurus A	FRI	$13^h\ 25^m\ 27.6^s$	-43° 01′ 08.8″	309.52	19.46	0.81
ESO 139-G12	Sy2	$17^h\ 37^m\ 39.5^s$	-59° 56′ 29″	334.04	-13.77	1
PKS 2005-489	HBL	$20^h\ 09^m\ 29^s$	-48° 49′ 19″	350.39	-32.61	1
PKS 2155-304	HBL	$21^h\ 58^m\ 53^s$	-30° 13′ 18″	17.74	-52.25	0.67
H 2356-309	HBL	$23^h\ 59^m\ 08^s$	-30° 37′ 39″	12.84	-78.04	0.67

Basic detector element: Storey